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From the Editors

September is biodiversity month, and in keeping with this theme we present four papers from the FNCV Biodiversity Symposium 'Impacts on Biodiversity during the Anthropocene' held in September 2015. Reflecting the Symposium theme, the papers here are diverse in their subject matter, with New discussing lepidoptera conservation, York and Friend reporting on fire management, Whiteley on animal diseases and Christie and Awal on invasive marine pests.

Added to these is a report of a range extension in yet another introduced species by J Murphy and we have an issue that is indeed suitably biodiverse.

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Front cover: Wildfire. Photo Department of Environment, Land, Water and Planning.
Back cover: Giant Fanworm *Sabella spallanzanii* at Point Cooke Marine Sanctuary. Photo Andrew Christie.

Lepidoptera conservation in urban environments: theory and practice

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Abstract

Urbanisation represents one of the most intensive, globally pervasive and largely irreversible sets of changes to natural and other terrestrial and freshwater environments, in which many ecologically specialised species succumb to pressures from widespread and adaptable generalists, including invasive aliens. Direct habitat loss and degradation, leading to fragmentation and isolation of populations, demonstrates the importance of remnant natural vegetation or wetland, and the dependence of numerous taxa on manipulated 'green spaces' within urban areas. Insect assemblages, and many individual species, depend on the resources available in such enclaves, and their connectivity within the wider urban landscape. The conservation of selected Australian Lepidoptera species illustrates the practicalities of attempting to conserve individual ecological specialists within urban environments. Three contrasting species (the Eltham copper butterfly *Paralucia pyrodiscus lucida*; Richmond birdwing butterfly *Ornithoptera richmondia*; Golden sun-moth *Synemon plana*) represent different urban threat scenarios, contexts and needs. Each is a notable flagship species for urban conservation and the focus of continuing conservation effort. The programs are compared to suggest wider needs for conserving threatened insects within urban landscapes. (*The Victorian Naturalist* 133(5) 2016, 160–164)

Key words: butterflies, moths, species conservation, urbanisation

Introduction

Increasing proportions of Earth's burgeoning human population dwell in cities and towns, with these continually expanding and becoming more intensively developed at the expense of more natural environments and the biodiversity they support. 'Megacities' are forecast to increase in number and size, with the current largest (Greater Tokyo, with more than 35 million people within a conurbation of 13 cities) perhaps becoming emulated elsewhere. Collectively, the changes to more natural environments as increasing amounts of periurban land are engulfed for housing, industry and the supporting infrastructure (such as transport systems, water provision, waste disposal and recreational amenities) needed to sustain people, are one of the most serious global threats to numerous local and endemic animals and plants. In parallel with agroecosystem establishment and maintenance, the massive, often abrupt, changes to the parental environments during urbanisation cause direct losses of more natural biotopes and allow proliferation of alien species and their impacts, with those effects also extending to freshwater bodies, such as through run-off and pollution, and in some cases also affecting adjacent coastal areas.

In addition to these two universal and pervasive complexes of threat (habitat loss and degradation and impacts of alien invasive species), a number of more particularly 'urban threats' arise, some with serious consequences for native insects. As examples, paved surfaces (concrete, asphalt) directly remove habitat needed by ground-nesting bees and other insects; asphalt roads can induce misorientation of aquatic insects to polarised light, leading to futile oviposition on road surfaces; traffic can cause direct mortality; roadways may act as a barrier, isolating insect populations; light intensity in streets and buildings can attract phototactic insects from more natural areas and render them vulnerable to vertebrate predators; and 'heat islands' may affect development rates and tolerances of resident and adventive species. All these effects are discussed in a recent overview (New 2015) and are noted here simply as background to the complexity of appraising threats for any given urban insect assemblage or species. The collective consequences include many losses of species or populations, changes in composition of assemblages and communities, with changes in ecological functions due also to novel interactions from invasive alien

species. The widespread trend toward biotic homogenisation, as resident or endemic ecological specialist species and restricted ecosystems succumb to widespread invading generalists, including those deliberately introduced, emphasises the importance of conservation in urban environments as a central arena for many components of biodiversity to persist. Many native biota are restricted progressively to small remnant fragmented sites in which populations are increasingly vulnerable and isolated by largely inhospitable surrounding terrain, and their natural population structure disrupted. Many formerly widely distributed insects have little natural habitat and resources left in now-urban areas, and persist only on isolated and degraded remnant sites within the urban milieu.

Studies on selected insect groups (notably ants, bees, ground beetles and butterflies) along urban-rural gradients and in urban sites have (1) shown the changing relative presence of 'urbanophobes' and 'urbanophiles' and their ecological characteristics, and so (2) provided background for understanding the changes that occur and the needs and methods for prevention and remediation of changes and losses, as practical conservation. Butterflies and other Lepidoptera such as diurnal moths are a potent insect flagship group, contrasting with most other insects in their wide public appeal and acceptance that they are worthy of conservation. This sympathy is accompanied by reliable species-level taxonomy, considerable biological knowledge, and awareness of the factors that constitute threats or that influence their wellbeing. Close association of many species with specific vegetation (as larval food and adult nectar sources) provides a tangible framework for defining critical resources, with their provision and accessibility a major component of practical conservation. Many species have become demonstrably threatened by urbanisation. Many conservation programs for threatened urban butterflies have been undertaken, especially in the temperate northern hemisphere. This paper illustrates some of the varied contexts in which Lepidoptera conservation needs have arisen in urban areas of eastern Australia, and the scope of species management plans for three key species: Eltham copper butterfly *Paralucia pyrodiscus lucida*; Richmond birdwing butterfly *Ornithoptera richmondia*; and Golden sun-moth *Synemon plana*).

Contexts and cases

The varied ecology of butterflies and moths, and the varying processes contributing to habitat loss and change in urban areas, ensure that each individual species may have rather different combinations of threats and conservation needs within the individual regional pattern of ecosystem change. The three Australian species discussed briefly below illustrate this variety. Synthesis from these and others helps to establish general conservation principles with wide application in urban environments. The two contrasting butterflies are subjects of the longest-running insect conservation campaigns in Australia, and have attracted much official attention and public support, with 'citizen science' campaigns integrated into wider conservation management. Their importance and conservation strategies are summarised by New (2011, Eltham copper) and Sands and New (2013, Richmond birdwing). The concern for the third example, the Golden sun-moth, is more recent, and has wide ramifications for urban development, through its role in confrontations between land developers and conservationists seeking to protect remnant native grasslands close to some major settlements, most notably on periurban areas scheduled for new suburbs and industrial parks close to Melbourne, Victoria (New 2014). Their differing urban contexts are outlined below. All are endemic ecological specialists with biological requirements that render monitoring and management complex, and all are formally protected taxa in Australia.

The Eltham copper butterfly Paralucia pyrodiscus lucida *Crosby (Lycaenidae)*

The few remnant populations of this locally endemic subspecies near Melbourne each occur on small (ca 1-2 ha) remnant open eucalypt woodland patches to which they have been confined by housing developments. Each population is isolated by housing and roads, and sites are subject to successional changes, weed invasions, run-off from nearby roads, and general disturbance. Larvae feed only on Sweet

Bursaria *Bursaria spinosa* Cav. and are tended obligatorily by ants (*Notoncus* spp.); they feed nocturnally and are 'herded' up Bursaria by ants, and shelter by day in the subterranean ant nests near the plants. Conservation, undertaken continuously since 1987, focuses on site protection and resource supply. Each site has individual needs, so that management is necessarily long-term and intensive, and the butterfly is conservation-dependent. It also has significant flagship value within the local community and has been adopted widely as a local 'icon'. Management to regenerate succession, control invasive weeds, reduce ground debris and open up the tree canopy to benefit low-growing Bursaria has included control burns orchestrated to cause minimum harm to the butterfly. Extensive community participation (led by an active Friends of the Eltham Copper group) and education, through local primary schools and others, have been continually and strongly supported by local authorities. The practical support of volunteers has been instrumental in conducting annual larva counts at night, and conducting daytime transect surveys for adult butterflies, as well as in practical management such as weed and rubbish removal from sites. The novelty of the tripartite association ('plant–butterfly–ant') has considerable public and educational appeal.

The Richmond birdwing butterfly* Ornithoptera richmondia *(Gray) (Papilionidae)

This strongly flying forest birdwing was previously distributed widely along coastal regions of southern Queensland and northern New South Wales but disappeared from most of this range (including the city of Brisbane, where it was formerly common) during the 20th century. The two reasons for this decline are (1) clearing of native vegetation for urban or agricultural conversion, with direct loss of habitat in and around settlements, and (2) the importation and spread of an alien South American vine (*Aristolochia elegans* Mast), initially a garden ornamental but subsequently widespread in natural areas. The vine attracts female birdwings to oviposit, but the foliage is toxic to developing larvae, which die after feeding. Conservation has focused on the twin activities of removal of the alien vine and extensive replacement and augmentation plantings of the native food plant, *Pararistolochia praevenosa* (F. Muell.) M.J.Parsons. The conservation program, undertaken since the late 1980s, has embraced the entire historical documented range of the butterfly but with a strong focus on urban areas such as Brisbane, with continued support of local people and schools in both the above activities. Planting of nursery-propagated *P. praevenosa* has emphasised (1) enhancement of these in remnant sites, including any occupied by the birdwing, and (2) planned plantings in natural corridors, to link those sites in the expectation that the birdwing may progressively and naturally re-colonise. Vines have also been planted in many home and school gardens, where they are monitored continually for the butterfly or its conspicuous larvae. Early appeal of the project is indicated by more than 29 000 vines being distributed by 1998, with more than 420 schools involved in the project, and coordinated through the national CSIRO Double Helix Science Club for young people. More recent community activities are coordinated and publicised through the Richmond Birdwing Conservation Network, through activities such as an informative newsletter, meetings and workshops.

The Golden sun-moth* Synemon plana *Walker (Castniidae)

Representing an endemic group of diurnal moths, *Synemon plana* occurs on remnant native grasslands, regarded as one of Australia's most endangered ecosystems on the south-eastern mainland. The major conservation emphasis is to prevent remaining grassland from undergoing development in the face of severe pressures for land resumption for housing (including entire new suburbs) and industry, especially near Melbourne. The sun-moth is one of a small portfolio of flagship species in this wider conservation endeavour. The moth's unusual biology makes populations very hard to assess or even detect—larvae feed underground, so are largely inaccessible for sampling, and adults are short-lived (1–5 days), do not feed, and emerge continuously over a flight season of about 8–10 weeks on any site. Only males fly readily, and females are much less active. Additional complications are that the generation

time is unknown, suggested to be one, two or three years, and that moths fly only under particular weather conditions and for a few hours in the middle of the day. This may be offset by monitoring empty pupal cases that protrude from the ground and persist for three weeks or more (Richter *et al.* 2013). In short, population assessments and detecting the moth require repeated visits over a season, by people who are aware of the sampling uncertainties involved, and preferably over several years to detect annual cohorts of a possible non-univoltine development pattern. Such protracted evaluations are contrary to the needs of developers seeking rapid approval for their activities to proceed. Inspection of grassland sites for the sun-moth (which is designated nationally as 'critically endangered') is mandatory in environmental impact assessments, with formal guidelines for the procedures and a detected population of five male moths triggering the need for further investigation as well as the possibility of designating habitat offsets if the project is to proceed. Extensive public concern and publicity for the moth has occurred. Management is further complicated by the implication that larvae may use the declared noxious weed Chilean Needle Grass *Nassella neesiana* (Trin. & Rupr.) Barkworth as an important food resource on some sites.

Discussion

The above examples help to display the variety of contexts that lead to the need for urban conservation of individual species of Lepidoptera. Further details for each are available from the references listed.

The Eltham copper exemplifies that some taxa can be conserved only by focusing on single small remnant sites embedded within a largely inhospitable matrix. These taxa are essentially conservation-dependent, imposing intensive and expensive continuing conservation management if they are to persist. There is little likelihood of the various Eltham copper habitat patches near Melbourne becoming functionally contiguous, and the greater likelihood is that some populations may already be in an extinction debt phase because of their very small size. If so, their demise from such small populations (or residual metapopulation units) may be hastened by stochastic events. At present, management continues on all occupied sites, with the aim of ensuring conditions suitable for the butterfly, its attendant *Notoncus* ant, and Bursaria within the natural vegetation community that includes other notable species such as some rare orchids. That approach incorporates continuing site protection and alleviating and preventing further threats, in the context of sustaining long-term suitability of those sites as natural succession occurs. The program depends on continued support from local government and people, both of which are universally essential in insect species conservation programs, together with education and publicity to foster interest among young people.

The wider perspective engendered for the Richmond birdwing is of a wide-ranging, landscape-focused conservation program that still incorporates focal sites, but largely in the context of their roles in enhancing local richness as nodes in promoting connectivity through corridors. This contrasts with the above primary focus on site dependence. Restoration of degraded habitat (removal of the alien larval food plant) and extension of overall occupiable area by providing critical resources (planned plantings of the natural larval food plant) are the twin major activities of a program with massive public appeal. The actions needed are easy to understand and execute, and the spectacular butterfly is easy to detect and monitor. Range extension is by natural flight dispersal, rather than any deliberate translocation, a tool sometimes used for less vagile species.

Both the butterflies discussed above exemplify the very common scenario of increasing the value of occupied sites by measures such as legal protection, resource enhancement, removal and prevention of threats, and promoting connectivity where possible. The emphasis on restoration changes for the Golden sun-moth, with the primary aim to protect existing inhabited remnant grassland areas in the face of developer pressures that could lead to their rapid loss, is a scenario of political and economic conflict with the potential to affect urban planning as demand for building sites increases into periurban areas. There are many parallels elsewhere in the world.

The three scenarios exemplified by these species thus differ in scale and focus, but with the commonality of urban involvement, with past or continuing urbanisation being the primary threats to each taxon. They emphasise the importance of understanding the biology of the focal species as a basis for effective management, the landscape context of conservation need, combined with the security of focal sites and the need for long-term and effective monitoring and adaptive management. Education and involving the local community, both as young people and as citizen scientists, in any such program is vital, together with effective communication and coordination of conservation activities in the long-term, sometimes over decades.

Urban environments create many needs for conservation, but also many opportunities for this to occur. The vast variety of urban 'open spaces', from large parks, remnant reserves and brownfield sites to small home gardens and novel habitats such as 'green roofs' can in many cases be manipulated to harbour increased native biodiversity, or foster wellbeing of focal threatened species. By increasing floral and structural diversity, as the most manipulable environmental features with which numerous insects (including most Lepidoptera) associate, local community richness and assemblage composition can be both protected and enhanced. Such measures include active protection of natural urban remnant sites and promotion of less intensive management of open spaces (e.g. by decreasing sanitation measures by reducing mowing frequency and leaving some weedy plants in parks or flowerbeds). These are all activities in which Lepidoptera can become significant umbrella taxa, accepted as such across these spatial scales by both 'top-down' (local government or other agency) and 'bottom-up' (individual householders or neighbourhood groups) managers. The latter, for example, may create 'butterfly gardens' and/or become involved in local issues, and are exemplified well by the 'Friends' groups that support each of the species noted above.

Urban environments present abundant opportunities to harmonise insect conservation with human recreational and amenity needs. These can be undertaken in conjunction with wise urban planning and landscape design to promote connectivity between open spaces, and in combination with surveys to determine the extent and needs of native biodiversity. The urban arena is a vital component of conserving our natural biological heritage. Lepidoptera, whether considered as individual threatened taxa or as conspicuous and relatively easily studied assemblages in which reasons for change can often be defined, are important in wider urban conservation endeavours throughout the world.

Acknowledgement

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Towards an ecologically sustainable fire management strategy

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Abstract
Fire is an important driver of ecosystem structure and function in Australia, and the study of these interrelationships has seen the development of a strong fire ecology discipline across the nation. Nowhere has this been stronger than in Victoria, which over the past 30 years has seen the refinement of an adaptive and innovative fire ecology framework, and its implementation and testing within an evolving policy setting and through a monitoring, evaluation and reporting framework. This paper outlines the key historical aspects of this rapidly evolving discipline within Victoria. (*The Victorian Naturalist* 133 (5) 2016, 165-171)

Keywords: planned burning, fire ecology, fire management, ecosystems

Introduction
Ecological principles currently inform strategic fire management planning in Australian states and territories, although this inclusion has a relatively recent history. The change has been driven primarily by a greater call for accountability in land management, but also by a realisation of the important role that fire plays in our ecosystems. Here we present a short historical overview of some of the important developments in this rapidly evolving field, with a focus on Victoria.

Fire has considerable antiquity in Australia. An analysis of charcoal records over the past 70 000 years indicates fire as prominent in the landscape, with the amount of vegetation burnt largely a function of climatic variation over that time (Mooney *et al.* 2012). While there is considerable debate concerning indigenous use of fire (Pyne 1991; Gammage 2011; Williams *et al.* 2015), after European settlement there was a marked increase in biomass burning associated with land clearing and agricultural development (Fig. 1). Fire as a land management tool, however, often had unplanned consequences. During the late 19th and early 20th centuries Victorian communities experienced a number of devastating bushfires: 'Black Thursday' 1851 (12 deaths); 'Red Tuesday' 1898 (12 deaths); 'Black Sunday' 1926 (60 deaths); 'Black Friday' 1939 (71 deaths). The findings of the Stretton Royal Commission held after the 1939 fires (Stretton 1939) were significant in raising fire awareness and prevention measures throughout Australia. A largely volunteer fire brigade movement was supplemented by more modern firefighting organisations and a shift from purely fire suppression to fire prevention began to gain momentum (Luke and McArthur 1978; Gill 1981).

Fire prevention meets biodiversity conservation
The 1940s and 1950s saw early policies of fire exclusion to protect timber resources replaced by programs of prescribed burning (nowadays referred to as planned burning), facilitated by the development of fuel behaviour guides, improved aerial ignition capacity and postwar technological advances (Luke and McArthur 1978). Gradually, from the mid-1950s onwards, broadscale planned burning programs were introduced into the Victorian landscape (Fig. 2). The 1960s and 1970s also saw the growth in numbers of conservation societies in Victoria and increasing concern about the impact of widespread planned burning on landscape values, particularly non-wood values (Gill 1981). Conflict developed between proponents of planned burning and environmentalists, particularly in areas set aside for conservation (e.g. national parks) (Moulds 1967).

Conscious of the debate concerning possible effects of this new fire prevention strategy on Australian temperate forests, research projects

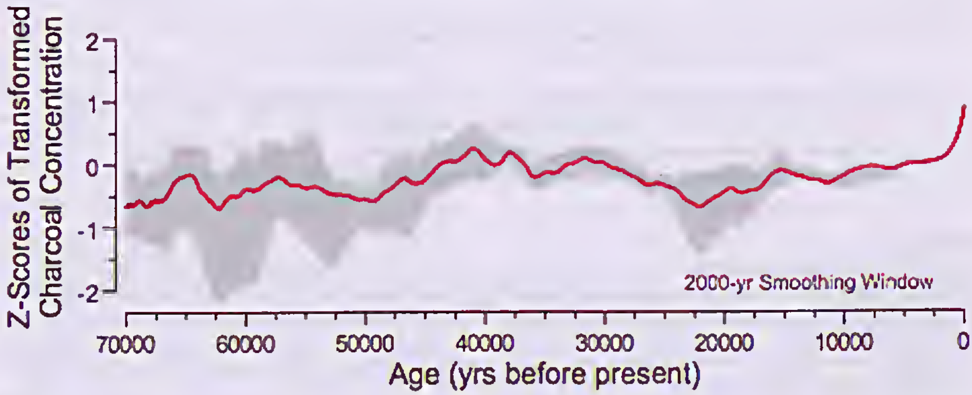

Fig. 1. Estimate of biomass burnt, based on a synthesis of 224 sedimentary charcoal records from Australasia during the last glacial (70 000–0 years before present). Reproduced from Mooney *et al.* 2012, with permission from CSIRO Publishing.

were established by forest management agencies in southern Queensland (Bauple State Forest long-term fire experiment; see Lewis and Debuse 2012) and NSW (e.g. the Bulls Ground Frequent Burning Study; see York 2000). These were later augmented by the Eden Burning Study Area in southern NSW (see Binns and Bridges 2003) and the Wombat Fire Effects Study in central Victoria (see Tolhurst and Flinn 1992). While initially focusing on the effects of planned burning on timber supplies, these projects all diversified to include a strong biodiversity component and became the basis for much of the later developments in fire ecology research and management policy.

A framework for fire ecology

With anecdote and opinion largely driving debate around fire and conservation issues in the 1960s and 1970s, scientists needed a structured framework with which to examine data and draw objective conclusions. Such a framework was provided by Malcolm Gill, whose 'Fire and the Australian flora: A review' (Gill 1975: 21) provided a 'basis for discussion of guiding principles in the use of fire regimes as management tools'. The fire regime concept provided the theoretical basis for subsequent research and continues to underpin fire science and management in Australia today. The concept of plant 'vital attributes', developed by Noble and Slatyer (1980), classified plants by their (i) method of arrival or persistence during and after disturbance (e.g. seeder, resprouter), (ii) ability to establish and grow to maturity, and (iii) the time taken to reach critical life stages (e.g. reproductive maturity). An understanding of how the fire regime influences vegetation communities through its interaction with species' vital attributes allows us to both understand observed responses of plants to fire (death/persistence), and then predict changes to populations and communities after subsequent fires (e.g. succession).

Development of ecologically-based fire regimes

This framework facilitated a dramatic increase in fire ecology research and knowledge, generating numerous scientific reports and papers subsequently summarised and integrated in a series of influential books (e.g. Gill *et al.* 1981; Whelan 1995; Bradstock *et al.* 2002, 2012). Equally important was the coordination of workshops and symposia that brought researchers and land managers together. The biennial 'Australian Bushfire Conference series (1987–2006, 2016)' and Nature Conservation Council of NSW 'Bushfire Management Conference' (1994 to present; see http://www.nature.org.au/healthy-ecosystems/bushfire-program/) facilitated a regular exchange of ideas concerning ecologically appropriate fire management. In 1994, the Victorian National

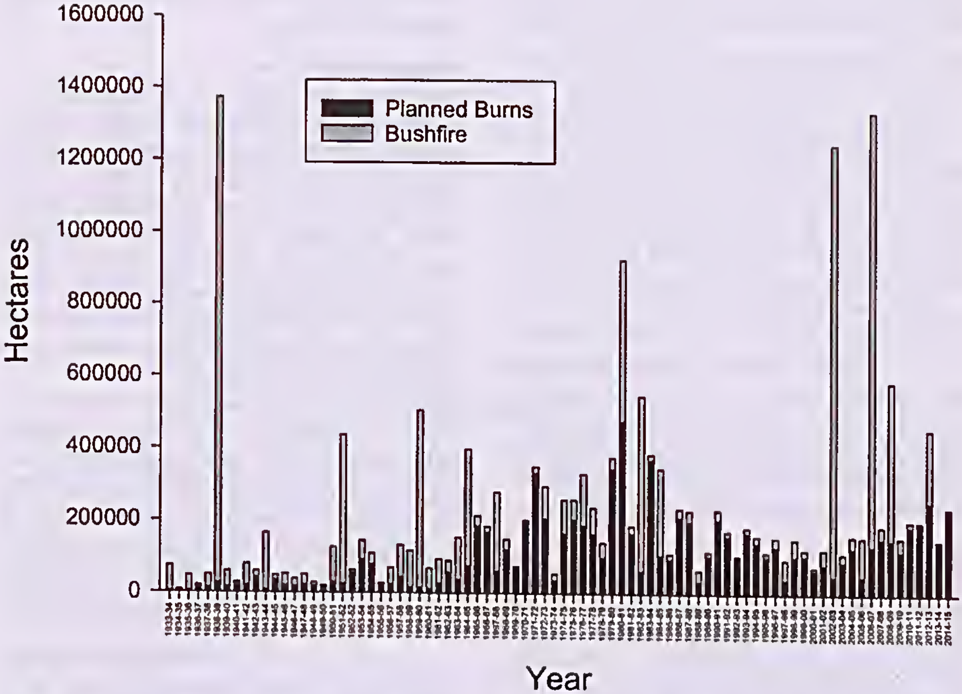

Fig. 2. Area burnt in Victoria 1933-2015 by bushfire and planned burns. Note: Planned burn data represent area treated and may be an overestimate of the area actually burnt. Data obtained from annual reports tabled in Parliament; Figure courtesy of the Victorian National Parks Association.

Parks Association and the Department of Conservation and Natural Resources hosted 'Fire and Biodiversity. The Effects and Effectiveness of Fire Management' (Commonwealth of Australia 1996). This meeting built on earlier conferences to showcase applied fire ecology and engage in meaningful discussion with management agencies.

In Victoria in 1998, those agencies responsible for park and forest management entered into a unique partnership designed to improve the understanding of the role of fire in the maintenance of biodiversity. The Department of Natural Resources and Environment (DNRE[1]) and Parks Victoria initiated a Steering Committee, a Working Group and Regional Reference Groups, and held a series of workshops across Victoria (Friend *et al.* 1999). The Working Group subsequently produced a set of guidelines for ecological burning (Fire Ecology Working Group 2004) which set out the policy framework, key principles and procedural framework for ecological burning on public land. It drew heavily on the science that had developed around an understanding of fire regimes and plant vital attributes. Vital attributes could be used to define Key Fire Response Species (KFRS), species whose attributes indicate that they are vulnerable to either a regime of frequent fires or to long periods of fire exclusion. Tolerable Fire Intervals (TFIs) for a given community or vegetation type were then identified, where the shorter TFI is set by the species that takes the longest time to reach reproductive maturity and the longer TFI is set by the species with the shortest time to local

[1] There have been numerous changes in the agency name over time, including: DNRE; Department of Sustainability and Environment (DSE); Department of Environment and Primary Industry (DEPI); Department of Environment, Land, Water and Planning (DELWP).

extinction as a result of senescence. TFI forms the ongoing basis for monitoring landscape condition and reporting ecological impacts of fire management in Victoria, although it is currently being supplemented by additional metrics (see below in Recent developments). These Guidelines complemented a second substantive document (Tolhurst and Cheney 1999) which summarised the broad suite of scientific principles that underpinned the operational use of planned burning. To help implement ecological strategies across public land, nine Fire and Environment Planning Officers (FEPOs) were appointed within Parks Victoria in 2004, while in 2005 the *Code of Practice for Fire Management on Public Land* was revised to include these new fire ecology structures. Ongoing development of the Fire Ecology Program saw the release of a *Strategic Directions* document (DSE 2006) outlining a substantial investment in ecological research and monitoring programs.

Including fauna

While it was recognised that shelter, food and breeding requirements largely determine an animal species' response to fire and its post-fire successional patterns (Fire Ecology Working Group 2004), explicit fire management strategies for fauna were limited to those regarded as of particular conservation significance. As pointed out by Clarke (2008), ecological fire management is often built on the assumption that meeting the needs of plant species will automatically meet the needs of animals. Management frameworks provide little guidance regarding the characteristics of desirable 'mosaics' of fauna habitat (e.g. patch size, connectivity or composition of successional (time since fire) stages). To address this issue, and the knowledge gap concerning the fire response of most animals, the Arthur Rylah Institute developed an approach that used existing data and expert knowledge to estimate the response of particular animal groups to disturbance (MacHunter *et al.* 2009). They generated hypothetical response curves (Fig. 3) which could be used to estimate the change in population size of faunal species following disturbance such as fire. This information could be used in conjunction with post-fire vegetation responses (Cheal 2010) to link animal numbers to post-fire growth (seral) stages, going part-way to understanding how fire mosaics (patches of different age) might influence overall animal numbers and hence population viability.

Managing landscapes

Ecosystems are naturally heterogeneous, a function of topography, soils, climate and disturbance history. Disturbance regimes affect environmental heterogeneity by resetting successional processes, over time producing a 'shifting mosaic' or 'mosaic cycle', providing perpetual resource complexity at a range of spatial scales and facilitating species' coexistence (Di Stefano and York 2012). Environmental heterogeneity at a range of spatial scales is fundamental to the maintenance of biodiversity.

Following the large and significant 2003 and 2006–2007 bushfires, DSE became increasingly concerned that such extensive fires were reducing landscape heterogeneity. The DSE Fire Ecology Program instigated major reviews of fire and its relationship to ecosystem resilience, disturbance regimes and landscape heterogeneity (McCarthy 2012; DiStefano and York 2012), which provided the basis for future work and policy development on ecosystem resilience and fire management (see below in Recent developments). DSE also initiated a plan to increase the amount of planned fire in the landscape to break up large homogeneous areas while still providing the right mix of fire at appropriate frequencies, seasons, intensities and scales. It was anticipated that this 'mosaic burning' undertaken at a landscape scale would help reduce the size, severity and impact of large-scale fire events, and maintain healthy and resilient ecosystems (DSE 2009). The Landscape Mosaic Burning program was introduced in 2009 in an Adaptive Management context, accompanied by a substantial investment in research with partner institutions. Research projects investigated aspects of fire refuges in the Central Highlands (e.g. Robinson *et al.* 2013; Leonard *et al.* 2014), fire mosaics in East Gippsland (Muir *et al.* 2015) and the Otway Ranges (e.g. Sitters *et al.* 2014; Cohn *et al.* 2015). Outputs from this research have identified the strengths and weaknesses of using post-fire growth stages as surrogates for fauna habitat (e.g. Swan *et al.* 2015) and helped

Fig. 3. Hypothetical curves for the response of fauna to fire. In this example, animals show an initial decline in abundance following fire then increase to levels above or below their pre-fire abundance. From MacHunter *et al.* 2009. © State of Victoria, Department of Environment, Land, Water and Planning. Reproduced with permission.

refine our understanding of how other aspects of the fire regime and landscape features influence animal populations (e.g. Chia *et al.* 2015).

Recent developments

If we know the relationship between animal species distributions, their abundance and post-fire growth stages, then conceptually we can define a vegetation age class distribution that maximises biodiversity at a landscape scale. DiStefano *et al.* (2013) investigated which vegetation age class distributions maximised a measure of diversity (the geometric mean of abundance [GMA]) for a range of taxa in the heathy stringybark woodlands of western Victoria. They found that the optimal solution differed between taxa (vascular plants, birds, small mammals and terrestrial invertebrates) and proposed that the departure from the optimal solution could be used to quantify the impact of alternative management strategies. This approach was subsequently tested in Mallee landscapes (Kelly *et al.* 2014) and explored in a theoretical context as it relates to extinction risk (McCarthy *et al.* 2014; Giljohann *et al.* 2015).

The revised *Code of Practice for Bushfire Management on Public Land* (DSE 2012) sets out two primary objectives for bushfire management. The second of these has a strong environmental/ecological focus: 'To maintain or improve the resilience of natural ecosystems and their ability to deliver services such as biodiversity, water, carbon storage and forest products' (DSE 2012: 1). DELWP has recently developed a policy position for defining, measuring and reporting ecosystem resilience in the context of bushfire management. This policy underpins the overarching Monitoring, Evaluation and Reporting (MER) Framework for Bushfire Management on Public Land, a keystone document that DELWP has developed to track and report on the effectiveness of bushfire management on public land in Victoria (DELWP 2015; http://www.delwp.vic.gov.au/safer-together/healthy-environment.

At the landscape level, DELWP will continue to use TFI as a metric, reporting the proportion of areas within and outside TFI thresholds and on the proportion of the landscape burnt by planned burns and bushfires while already below minimum TFI. The GMA (known as *G*, see Buckland *et al.* 2011), derived from species abundances (see above), is to be used as a supplementary measure of the resilience of plant and animal communities (see McCarthy 2012). Concurrently, DELWP will be monitoring veg-

etation growth stage structure (GSS) based on the premise that a particular mix of vegetation growth stages and habitat structures across a landscape can potentially optimise biodiversity, and hence ecosystem resilience. The proportional change in *G* between the ecological goal and the observed (current) GSS for Ecological Fire Groups (vegetation classes; see Cheal 2010) will provide a measure of ecosystem resilience. In a resilient and sustainable ecosystem the difference in *G* between the ecological goal and the observed GSS will be minimal. This information can then be used to select a preferred management strategy and report on its effectiveness.

Future directions

Recent advances in defining ecologically appropriate fire regimes have allowed managers to move away from a narrow focus on fire sensitive vascular plants (KFRS) to include vertebrate animals in the development of monitoring and assessment protocols. A major challenge for the future will be to routinely include megadiverse (but currently excluded) groups such as fungi and invertebrates (New *et al.* 2010; McMullan-Fisher *et al.* 2011); groups that play essential roles in nutrient cycling and other ecological processes (York *et al.* 2012).

Refinement of resilience metrics is ongoing in conjunction with DELWP's research partners. Aspects of the goal GSS are strongly influenced by the way data are collected (sampling design) and which species are included (sampling efficiency and species priority). Should we give stronger emphasis to threatened or locally significant species, or should all species be weighted equally? A current assumption of the growth stage optimisation is that vegetation is contiguous (connected) across the landscape; however, much of Victoria's public land is fragmented by agricultural and urban development. Should fire mosaics be created in every patch or is there some scale at which we can manage patches together as one unit? Can we include some measure of an animal's dispersal capability and specific habitat requirement at different stages of its life in the calculations? Adaptive Management requires continuous learning and improvement, so refinement of resilience metrics and their implementation will be ongoing.

We have come a long way in the 30 years since Malcolm Gill introduced the fire regime concept, and made significant progress in incorporating ecological principles and objectives in the management of our fire-prone environments. As our biodiversity faces increasing threats from changing climate, pests and weeds, and altered fire regimes, it is essential that we have management strategies underpinned by rigorous science. Victoria is a leader in this field and will continue to support research to provide evidence-based policy development and to develop and test new ecological management models through the principles of adaptive management, as provided in the MER Framework.

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Beginning to understand some impacts of existing and emerging animal diseases

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Abstract
Wildlife health and disease are rarely considered, but disease affects growth and fitness, reproduction, mortality and morbidity. Mortality and mobidity are not frequently observed, reported or investigated so we have limited understanding of baseline wildlife health patterns. Disease in endemic wildlife has occurred because of introduced plants, spill over of infections from introduced domestic and feral animals, and from non-infectious diesease agents from urban development, industry, mining and agriculture. Wildlife Health Surveillance Victoria undertakes general wildlife disease surveillance, receives reports of wildlife health events to investigate and reports to Wildlife Health Australia. (*The Victorian Naturalist* 133 (5) 2016, 172-174)

Keywords: wildlife, disease, diagnosis, epidemiology, biosecurity, contaminants

Introduction

When field naturalists, bird observers, ecologists and others are in the bush they may be thinking about 'What wildlife lives here? What species, their sex, age, numbers and population trends?'. Wildlife health and disease are rarely considered. Disease is any impairment of normal function, including response to environmental factors (nutrition, toxicants, climate etc.), infectious and non-infectious disease agents, inherent or congenital defects, or a combination of these (Wobeser 2005). Disease and health affect growth and fitness (the ability to escape predators etc.), reproduction, mortality and morbidity (sickness) but are easily missed in the field. The clinical signs of morbidity include weakness, thinness or poor body condition and abnormal behaviour. However, mortality and morbidity of wildlife are not frequently observed, nor reported, nor investigated. Hence we have limited knowledge of baseline wildlife health patterns in free-ranging populations of endemic mammals, birds, reptiles and amphibians. Knowledge of baseline patterns is essential to detect changed morbidity/mortality patterns such as emerging spill-over, or emergency, usually of exotic or zoonotic diseases. Emerging diseases are new occurrences of a disease, infection or infestation, that results from a change of a known pathogenic agent or its spread to a new geographic area or species; or a previously unrecognised pathogenic agent or disease that is diagnosed for the first time (OIE 2016). Anyone who observes wildlife can contribute to this knowledge gap by informing Wildlife Health Surveillance Victoria (WHSV) at the Faculty of Veterinary and Agricultural Sciences of The University of Melbourne, or via state government agencies (Agriculture, Environment, Parks Victoria, EPA) for investigation.

Many factors affect the distribution and abundance of wildlife. Such factors include environment (vegetation, invertebrate vectors etc.), wildlife host (species assemblage etc.) and disease agents (infections, non-infectious disease agents, interactions between these). Moreover, human actions have affected these three areas by causing habitat loss and fragmentation; introducing invasive species; allowing the spread of infections from introduced domestic and feral animals; and producing environmental contaminants from industry, mining, agriculture and various urban activities. Car accidents and hunting cause mortality and morbidity.

Wildlife health is important because it can affect wildlife in three areas, namely wildlife and the environment (biodiversity conservation), domestic animals (biosecurity and food security) and humans (zoonotic diseases). The Australian Department of Environment has identified some diseases as key threatening processes. These include Psittacine Beak and Feather Disease circovirus, Tasmanian Devil

Facial Tumour and the introduced Chytrid fungus in amphibians. Introduced dogs and foxes have brought hydatids *Echinococcus granulosus*, which infects macropods, and sarcoptic mange or scabies *Sarcoptes scabiei*, which infects wombats and koalas. Introduced cats are the definitive host for Toxoplasmosis *Toxoplasma gondii* which contaminates the environment via their faeces, causing disease in marsupials such as bandicoots, wombats and macropods. However, the impact of Toxoplasmosis on marsupial biodiversity is not well understood. Animal infections can be transmitted in both directions between wildlife and domestic animals, creating wildlife reservoirs that are very difficult to manage. In all continents except Antarctica and Australia the zoonotic bacterial infection Bovine Tuberculosis *Mycobacterium bovis* has spread from domestic cattle to create wildlife reservoirs. Parasitic Liver Fluke *Fasciola hepatica* from sheep and cattle causes disease in macropods. Non-pathogenic avian influenza viruses can be spread from waterbirds to domestic poultry, where mutations can result in disease. Wildlife can also be the source of zoonotic infections for people. Ross River and Barmah Forest viruses are transmitted by mosquitoes and midges to humans from wildlife reservoirs where they are not known to cause disease, only infection. The zoonotic diseases Australian Bat Lyssavirus and Hendra virus both require close contact with bats, or horses infected from bats, respectively.

WHSV (Fig. 1) investigates unusual wildlife mortality/morbidity events and clusters of disease after being informed of these events by people who observe wildlife, such as field naturalists, bird observers, wildlife carers, veterinary practitioners, Landcare members and staff of state agencies and local government. This general or scanning surveillance is the 'most important component of a national wildlife health program' and 'the only way a country can know what pathogens exist in its wildlife' (OIE 2010: 34). Surveillance 'means the systematic, ongoing collection, collation and analysis of information related to animal health and the timely dissemination of information so that action can be taken' (OIE 2016: ix). Surveillance can also be targeted to a particular pathogenic agent, but this will fail to detect other diseases.

WHSV was established in 2008 to improve our knowledge of baseline patterns of disease in free ranging wildlife, to detect changed patterns, and investigate factors or drivers of change in host, agent, environment and interactions. WHSV is modelled on both the Canadian Wildlife Health Cooperative (based at Canada's veterinary colleges) and Wildlife Health Australia (WHA). WHSV relies on people from the Victorian community informing WHSV of wildlife health events. Sick wildlife is examined by local veterinary practitioners for animal welfare reasons. Wildlife found dead or euthanised are transported to the Faculty of Veterinary and Agricultural Sciences at Werribee for pathology. Field investigations are also undertaken, involving pathology, microbiology, parasitology, virology and toxicology to determine the causes of death and make diagnoses. Together with data about the wildlife host (species, age, sex, clinical signs, 'population at risk'—the denominator to calculate disease prevalence, number affected/number at risk) and the environment (other species, vegetation, weather, invertebrate vectors, etc.), epidemiology is used to describe and investigate disease in the population. Many of these investigations are collaborative with colleagues from other institutions and agencies involved with animal and zoonotic diseases or wildlife. Feedback is provided to the people involved, key governmental agencies, and results are reported into WHA's national electronic Wildlife Health Information System (eWHIS). WHA is expanding its national wildlife health surveillance program and has provided funding for data entry. Wildlife Health Australia website provides excellent fact sheets about a wide range of wildlife diseases. People interested in wildlife health can become members and receive a weekly email digest.

Since 2008, WHSV has undertaken approximately 100 investigations annually in Victoria, but if funding were available, this could be increased significantly and could be expanded to include feral animals. Veterinary students are involved with wildlife pathology investigations and undertake wildlife disease research projects. These include investigating Chlamydia and Beak and Feather Disease circovirus infections in psittacines, botulism in waterbirds, reviewing Eastern Grey Kangaroo and Southern

Fig. 1. Wildlife Health Surveillance Victoria framework. Please read from the bottom up.

Brown Bandicoot investigations and undertaking disease risk assessments. Collaborative investigations into incoordination (ataxia) and death in Eastern Grey Kangaroos caused by chronic *Phalaris* (introduced pasture plant) toxicity were published (Bacci *et al.* 2014). Other collaborative investigations and research include: Chlamydia and retrovirus infections in Koalas; Herpes virus infections in marsupials; Sarcoptic mange in Koalas; mortality/morbidity in juvenile Eastern Grey Kangaroos from high density populations due to a macropod blood-sucking nematode *Globocephaloides trifidospicularis* in their small intestines; diagnosis of zoonotic Bairnsdale ulcer caused by bacterial *Mycobacterium ulcerans* in possums from the Bellarine and Mornington peninsulas; mortality associated with necrotic enteritis of Rainbow Lorikeets in Melbourne in 2012; mass mortalities of shearwaters; surveillance for avian influenza virus in dead waterbirds; detection of pigeon paramyxovirus in feral pigeons; mortality of frogs due to Chytrid fungus and some undiagnosed events; investigating sick blue-tongued lizards (ongoing). We recognise there are many limitations to these investigations, but we are working systematically to expand this wildlife health knowledge. WHSV also identifies research needs and opportunities. If you are interested in more information or wish to support this project please contact Pam Whiteley. Donations made to WHSV through The University of Melbourne are tax deductible.

The WHSV website provides a flier approximately every three months to increase awareness of seasonal wildlife health issues. This can be printed for notice boards or forwarded to anyone interested in wildlife health. We wish to increase awareness and reporting of wildlife health events. Dead wildlife is useful. I am also keen to talk about this program with regional community groups and governmental agency staff, explaining how they can be involved, and report on and discuss local issues.

There is no need for undue concern about wildlife health and disease. Disease is a natural phenomenon. Native species have evolved with endemic diseases. However, human behaviours of moving animals (and their infections, introducing domestic and feral animals to Australia, smuggling, wildlife meat trade internationally), increasing toxic environmental contaminants, and changing human-wildlife and domestic animal-wildlife interfaces through access to water, intensive animal production waste disposal and expanding domestic animal production into natural areas have increased health risks for us all, (One World One Health 2004, Planetary Health 2016), and these should be identified and managed using Wildlife Disease Risk Assessment Guidelines (IUCN 2016). This is a significant task and requires collaboration, goodwill and wisdom.

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Invasive marine pests: the view from Point Cooke Marine Sanctuary

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Abstract

Introduced Marine Pest species (IMPs) have the potential to compromise biodiversity and have been shown to be detrimental to various marine habitats. This contribution provides an overview of the challenges and impacts of five IMPs within the Point Cooke Marine Sanctuary in Port Phillip Bay. Of these, four have been deemed to be so invasive and of such ecological importance that National Control Plans have been developed to combat their spread and influence on southern Australian marine waters. (*The Victorian Naturalist* 133 (5) 2016, 175-183)

Keywords: invasive marine pest species, Point Cooke Marine Sanctuary, Port Phillip Bay

Introduction

Introduced Marine Pest species (IMPs) are renowned for having the potential to compromise biodiversity, and have been detrimental in a number of ways to various marine habitats, including within Port Phillip Bay (Hewitt *et al.* 2004). At last count, it was suspected that there were over 120 organisms that were either introduced or cryptogenic (organisms of uncertain origin) (Hewitt *et al.* 2004) within this particular marine environment. The fact that so many IMPs are present in Port Phillip Bay should not be surprising, given that the Port of Melbourne is one of the busiest ports in Australia, handling in excess of 3000 ship movements per year (Port of Melbourne Corporation 2016). Furthermore, the popularity of recreational fishing and boating means that, once established, there are abundant opportunities for IMPs to be translocated to other sections of Port Phillip Bay and beyond, primarily by way of hull fouling (Cohen *et al.* 2000; Hewitt *et al.* 2004). It is believed that most international invaders of Port Phillip Bay arrived by way of hull fouling or ballast water discharges (Hewitt *et al.* 2004; Parry *et al.* 1996). Ballast Water Discharge Guidelines have been introduced to try to alleviate the incidence of exotic pest incursions. It remains to be seen whether such measures will ultimately be successful, especially in light of the increasing levels of ship traffic (Fig. 1) that have eventuated as a partial result of channel deepening and dredging, which was designed to permit the passage of vessels of very large draft (i.e. 'Panamax' class vessels) from international and domestic origins to Melbourne's ports.

Point Cooke Marine Sanctuary (PCMS) is a 290 ha marine protected area in Melbourne's west, about 25 km from the Melbourne Central Business District (Fig. 2).

PCMS features a wide range of habitats, including basalt reef and boulders, seagrass meadows, sand and mud patches. The tidal range at the sanctuary is equivalent to that of northern Port Phillip Bay, and varies by nearly a metre during the typical tidal cycle. The deepest parts of the sanctuary (which extends to a distance of over 600 metres offshore in some areas; Fig. 3) are around seven metres deep on a high tide. PCMS features a plethora of marine flora and fauna, with crustaceans, molluscs, echinoderms and fish being plentiful.

The sanctuary appears to be relatively diverse for its elasmobranch fauna, with many species of shark and ray abounding, including Port Jackson sharks, some of which have formed mass aggregations (Christie 2015).

At one stage, Wyndham Shire, to which the suburb of Point Cook belongs, held the distinction of being the fastest growing municipality in Australia, and in 2014–15, recorded 5% growth, making it one of the fastest growing areas in Victoria (Wyndham City Council 2016). The accelerated development of the region has completely transformed the suburb from a town with one main road, that effectively supported the local Royal Australian Air Force base, to a thriving community that has outgrown the lo-

Fig. 1. High levels of ship traffic offshore from Point Cooke Marine Sanctuary, showing vessels of various sizes which are regularly observed. Photos Andrew Christie.

cal infrastructure. This level of rapid urbanisation has been met by Melbourne Water and City West Water's commitment to developing man made wetlands in an effort to curtail or at least limit the inevitable increase in runoff levels that could infiltrate Port Phillip Bay and the marine sanctuary environs. However, in future years there could be unprecedented levels of pressure being exerted upon the PCMS, Point Cook Coastal Park and the surrounding environments. (Please note here that the spelling of Point Cooke Marine Sanctuary and Point Cook Coastal Park, and the suburb of Point Cook differ; Point 'Cooke' is technically correct, as it is a reference to John Cooke, an explorer based on the *HMS Rattlesnake* in the 1800s, after whom the region is named).

Macroalgal abundance varies throughout the sanctuary, with some of the more common native species being *Sargassum* spp. and the sea lettuce *Ulva* spp. The native brown kelp *Ecklonia radiata* appears to be relatively rare throughout the sanctuary (pers. obs.). Parts of the sanctuary are evidently being shaped by the overabundance of the purple sea urchin *Heliocidaris erythrogramma*, which has created numerous large urchin barrens (areas that have been stripped of macroalgae) (Fig. 4).

Fig. 2. The skyline of the Melbourne CBD visible from the shore of Point Cooke Marine Sanctuary. Photo Andrew Christie.

This contribution is intended to provide the reader with an appreciation of selected IMPs within PCMS against the backdrop of biodiversity in the Anthropocene, and will seek to provide an overview of the challenges that they pose and the impacts that these pests could be having within the marine sanctuary. Of the five IMPs that have been selected for further discussion here, four have been deemed to be so invasive, and of such ecological importance, that National Control Plans have been developed to combat the spread and influence that they have on southern Australian marine waters (Aquenal 2008). Some of these IMPs are deemed to be amongst the most invasive marine pests to have reached the southern Australian bioregion (Glasby and Creese 2007).

Meet Point Cooke's Introduced Marine Pests!

The following are summaries of the prevalence, and possibly potential impacts, of the IMPs within PCMS. The observations and inferences that follow are based on a multitude of snorkeling and SCUBA diving trips, intertidal and subtidal surveys (Fig. 5) and beachcombing exercises of the area from 1997 until the

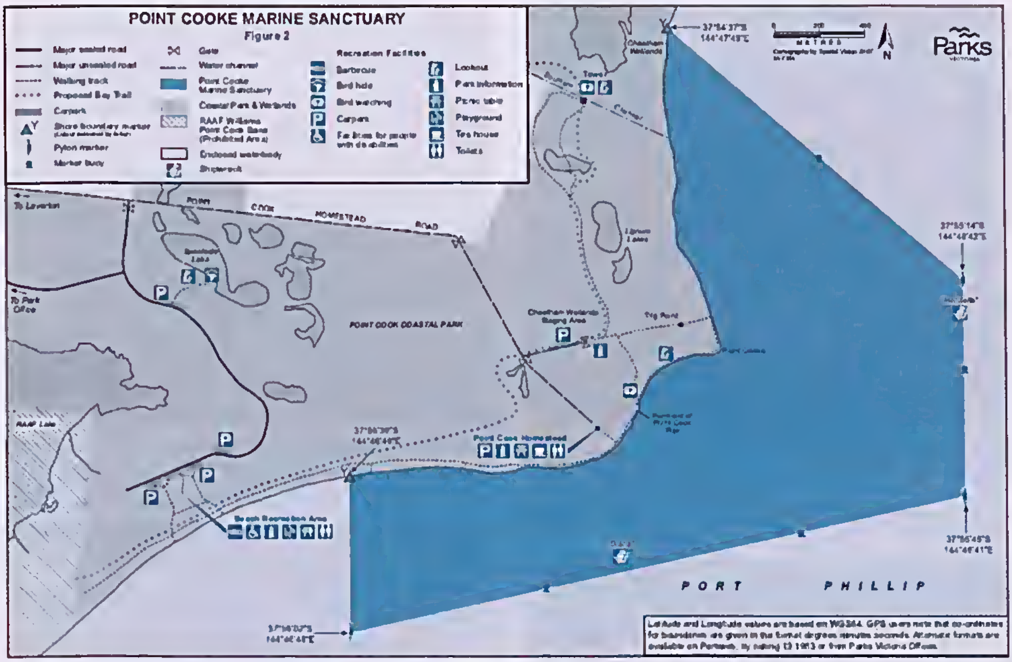

Fig. 3. The layout of the Point Cooke Marine Sanctuary (Source: Parks Victoria 2007).

present day. These are bound to extend into the future, with the involvement of volunteers from a number of friends groups, including Marine Care Point Cooke (MCPC), Jawbone Marine Sanctuary Care Group (JMSCG), and Marine Care Ricketts Point (these groups often interact with each other, and have a number of volunteers who hold memberships to multiple groups), as well as Melbourne Polytechnic and other tertiary or secondary educational groups that may have interactions with the area.

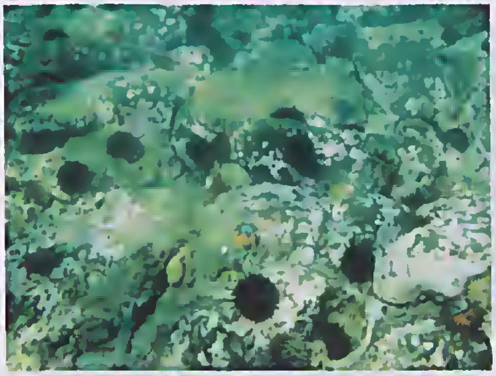

Fig. 4. An urchin barren at Point Cooke Marine Sanctuary. Photo Andrew Christie.

***Japanese Kelp or Wakame* Undaria pinnatifida**

This brown alga has been in Port Phillip Bay since the mid 1990s (Hewitt *et al.* 2004).

By far the most visible IMP in the sanctuary in terms of biomass, it seems likely that this seaweed exerts the greatest impact on the sanctuary of any of the IMPs. During the late autumn, winter and spring months, the alga grows at its most rapid rate, and is capable of forming

Fig. 5. Marine Care Point Cooke volunteers with a banner and kayak for conducting (native) sea urchin barren monitoring. Photo Jacqueline Flynn, Marine Care Point Cooke.

dense stands or 'forests' throughout many parts of the sanctuary (Fig. 6).

While the literature suggests that this species of macroalga is capable of astonishing growth rates of as much as 5 cm per day, it is likely that growth rates within the PCMS are far more modest (unpublished data). This macroalga experiences rapid dieback in the summer months, and can therefore be classified as being seasonal and annual (Hewitt *et al.* 2005); it does not regenerate once it enters the dieback phase (Fig. 7).

Despite *U. pinnatifida* being an edible seaweed, it remains to be seen how palatable it is to the purple sea urchin *H. erythrogramma*, the key urchin species within PCMS and the surrounding environment. Numerous instances have been noted over the years of *U. pinnatifida* seemingly growing unhindered in the middle of urchin barrens (Fig. 8), seemingly impervious to attack by the surrounding urchins. It is likely that *U. pinnatifida* establishes itself within sections of the sanctuary that are not as heavily populated with urchins as others, and its rapid growth rate allows it to establish dense populations in the presence of urchins, whereas the native kelp *E. radiata* is more susceptible to grazing pressure from urchins (Valentine and Johnson 2005).

Fig. 6. A dense stand of Japanese Kelp or Wakame *Undaria pinnatifida* at Point Cooke Marine Sanctuary. Photo Andrew Christie.

***Japanese Slippery Weed* Grateloupia turuturu**

This marine pest species (Fig. 9) was discovered during the 'Two Bays' cruise (a scientific expedition aimed at improving knowledge of Port Phillip and Westernport Bays) from the research catamaran, the *MV Pelican*, in February 2010. This red alga looks very similar to some native varieties, but it is thought to be distinguishable microscopically and by its texture; *G. turuturu* has a slippery feel, hence its common name. It is uncertain whether many of the intertidal grazers that are present in large numbers (notably *Austrocochlea* spp.) feed on this alga. The biomass of this alga, particularly within the intertidal zone, has increased dramatically since it was first detected within PCMS. This is a situation worthy of ongoing monitoring to determine its level of impact.

***Giant Fanworm* Sabella spallanzanii**

Giant Fanworm is easily distinguished from native varieties by the impressive two-tiered 'fan' arrangement of radioles that are often fully deployed from the tube in which the animal resides (Fig. 10). The radioles are capable of filter-

Fig. 7. Two examples of Japanese Kelp *Undaria pinnatifida*, at Point Cooke Marine Sanctuary, pictured in July (left), and when dieback has occurred in December (right). Photos Andrew Chrisite.

Fig. 8. Japanese Kelp *Undaria pinnatifida* growing amongst urchins at Point Cooke Marine Sanctuary. Photo Andrew Christie.

Fig. 9. Japanese Slippery Weed *Grateloupia turuturu* in the intertidal zone of Point Cooke Marine Sanctuary. Photo Andrew Christie.

Fig. 10. Giant Fanworm *Sabella spallanzanii* showing a close-up of the distinctive spiralled crown of tentacles. Photos Andrew Christie.

ing an enormous amount of water every hour, and as suspension feeders their key ecological role appears to be the provision of competition for other filter and suspension feeders, such as sponges and cunjevoi (sea squirts), which are both very common throughout the marine sanctuary. At PCMS, these animals appear to be quite patchily distributed; lone individuals or clumps of three or four individuals are quite common throughout the sanctuary, especially in areas such as subtidal seagrass meadows and basalt reef at depths of between five and seven metres. Some areas are clearly 'hotspots' for *S. spallanzanii* (Fig.11), and in these areas they must be exerting a considerable influence, though the densities observed are relatively minimal compared to the massive densities that are observed on some anthropogenic structures such as Gem Pier in Williamstown and throughout the Corio arm of Port Phillip Bay, where this IMP was first detected back in the late 1980s (Carey and Watson 1992).

It is interesting to note, though, that marine pests will invariably be integrated somehow into the local ecology (Rilov 2010), with some of the larger Sabellids in the sanctuary attracting an enormous number of fouling organisms, and seemingly functioning as artificial reef structures themselves (Fig. 11)!

***European or green shore crab* Carcinus maenus**

This crab (Fig. 12) appears to be quite common, without being abundant, in the sanctuary, judging by the number of carapaces of either moulted or dead animals, that are washed up on the shore. A voracious predator of bivalves, particularly *Katelysia scalarina*, the green shore crab's impact in the sanctuary is hard to gauge because, like many other crabs and crustaceans, it is nocturnal. The adjacent Point Cook Coastal Park, through which PCMS is accessed, is closed well before sundown, after which the marine sanctuary is accessible only by boat. The actual numbers, feeding behaviour and therefore impact of this animal is unknown, but it could

Fig. 11. A relative 'hotspot' of Giant Fanworm *Sabella spallanzanii* photographed at a depth of approximately six metres at Point Cooke Marine Sanctuary (left) and the considerable build-up of fouling organisms on the 'tubes' of some of the larger individuals in a separate heavily infested area (right). Photos Andrew Christie.

be much greater than is currently thought. Of all the IMPs at PCMS, the habits of this species make its contribution perhaps the most difficult to quantify. However, the prosobranchial marine gastropod population at PCMS appears to be extremely healthy, with massive numbers of *Austrocochlea* spp. and *Bembicium melanostoma* recorded in routine intertidal surveys by the volunteers of MCPC under the auspices of Sea Search and Parks Victoria.

Northern Pacific seastar Asterias amurensis

While it was detected in the marine sanctuary from at least the mid to late 1990s, it appears that numbers of this notoriously damaging marine pest (Fig. 13) within PCMS are minimal, and it therefore appears to have exerted relatively little impact on the sanctuary and the immediate surrounds. I recall seeing examples of *Asterias amurensis* at PCMS in 1997, and assumed (perhaps understandably) that these seastars were going to dominate the entire marine sanctuary and surrounding region. It has been fascinating to see that *A. amurensis* has not established a foothold at the PCMS, nor at the nearby JMSCG in Williamstown, and at the time of writing remains a relatively rare inhabitant of the sanctuary. One reason for the low numbers may be that *A. amurensis* faces strong competition from a multitude of native seastars, particularly the eleven-armed seastar *Coscinasterias muricata* (known to exhibit predator behaviour towards *A. amurensis*) and *Meridiastra calcar*, which are both present in large numbers throughout the PCMS.

Asterias amurensis is capable of incredible foraging capacity, demonstrated in Fig. 14, where an animal is able to subjugate and feed on a bivalve gastropod despite possessing only one full sized arm.

Although the volunteers of the friends groups of MCPC and JMSCG have conducted numer-

Fig. 12. European or green shore crab *Carcinus maenus* pictured at Point Cook Marine Sanctuary, perched on a dive glove for scale (left), and a carapace washed up on the shore (right). Photos Andrew Christie.

Fig. 13. Northern Pacific seastar *Asterias amurensis*. Photo Andrew Christie.

Fig. 14. An individual Northern Pacific seastar *Asterias amurensis*, with only one arm, and two arms regenerating, attempts to feed on a bivalve gastropod *Katelysia scalarina* at Point Cooke Marine Sanctuary. Photo Andrew Christie.

ous removals of *A. amurensis* in concert with other activities (notably marine debris clean-ups and participation in events such as the Great Victorian Fish Count), it is unlikely that these would have made a tangible difference to the number of *A. amurensis* in these sanctuaries, let alone the eradication of the species from the area (Fig. 15). While both localities have considerable numbers of bivalve gastropods (the favoured prey item of the seastar), it appears that *A. amurensis* has not invaded these sanctuaries to any marked degree. Densities of this seastar have no doubt fluctuated over the years, with massive densities previously observed adjacent to Gloucester Reserve (itself directly adjacent to JMSCG) in Williamstown. Huge densities are regularly encountered throughout various sections of St Kilda. Both locations are a short distance from PCMS.

It will be fascinating to see whether the distribution of *A. amurensis* changes within PCMS over the next few years; it is hoped that this pest stays away from the sanctuary for the good of biodiversity within this precious area.

Removals of marine pests from Point Cooke Marine Sanctuary: where to from here?

Friends groups have a vital role to play in marine protected areas. MCPC has participated in events such as intertidal surveys for Sea Search, and the Great Victorian Fish Count for Reef Watch, which are aimed at quantifying the current state of the sanctuary.

The documentation of the extent of invasions and the potential impacts various IMPs may have is a key goal of MCPC. One of the key questions facing friends groups such as MCPC and organisations such as Parks Victoria is what to do with marine pests once they appear within a particular environment. Physical removals can be quite arduous and time-consuming, and a key consideration is how often they need to be practised in order to keep the numbers of marine pests down to a desired level. This in combination with the fact that some species, such as *U. pinnatifida*, are best targeted during some of the coldest months of the year (when temperatures may be as low as 8°C), means that physical removal is beyond the will, capability and interest of many members of friends groups.

Of the five marine pests mentioned here as being of concern at PCMS, only *U. pinnatifida* has any recognised commercial value. This edible seaweed (Fig. 16), which is also known as Wakame, can be dried and processed, is widely available in Asian grocery stores, and could well provide a financial incentive to the friends groups that choose to remove it if a suitable processor and distributor can be found. There are some concerns that *U. pinnatifida* harvested in Port Phillip Bay could contain some contaminants from the greater Melbourne catchment area, and research is continuing in this regard, particularly with on the levels of heavy or trace

Fig. 15. Andrew Christie and Kirstie Knowles of Marine Care Point Cooke following an *Asterias amurensis* remopval day at Point Cooke Marine Sanctuary in January 2014, which netted a grand total of only two seastars (left). Photo Mal;colm Wrest, Marine Care Point Cooke. Right: *Asterias amurensis* collected during a removal day in January 2013. Photo Andrew Christie.

metals within the tissues of the *U. pinnatifida* (Dr Alicia Bellgrove, Deakin University, pers. comm). Because this seaweed is essentially an annual species with a short lifespan and rapid growth rates, it is possible that bioaccumulation of toxicants may not occur at the level required to cause human health concerns, but this requires the appropriate level of testing.

A project is being undertaken to try to determine the level of collateral damage incurred by removal of *U. pinnatifida* from the marine environment; anecdotal observations have demonstrated that gastropods, amphipods, seastars and even fish are sometimes unwittingly placed into catchbags by well-intentioned volunteers, since these faunal items are presumably using this invasive macroalgae for food and/or shelter.

A key consideration for *U. pinnatifida* is what the consequences may be for failing to remove it from areas such as marine sanctuaries. Intuition suggests that these marine pests could 'spill over' from marine protected areas but it appears that the dispersal radius for *U. pinnatifida* is relatively short, with gametes said to travel only 50 m or so before they start to lose their viability (Dr Steffan Howe, Parks Victoria, pers. comm. 2014). This could help explain why populations within Port Phillip Bay are relatively localised, and why there is only one population known to exist outside Port Phillip Bay, in Apollo Bay Harbour. It could be that the *U. pinnatifida* populations within PCMS are unlikely to cause many problems within the rest of Port Phillip Bay. Indeed, *U. pinnatifida* could actually be considered an asset in areas that are otherwise completely devoid of macroalgae, as is the case within urchin barren habitats.

Fig. 16. Caroline Esbenshade of Marine Care Point Cooke sitting down to a meal of pink ling stew with commercially prepared *Undaria pinnatifida*. Could this represent an opportunity for the funding of friends groups with an interest in the conservation of the marine environment? Photo Andrew Christie.

Table 1. Arbitrary rating of 1 to 5, where 1 represents low rating and 5 represents greatest rating, of abundance, potential impact and apparent impact of the five key IMPs within Point Cooke Marine Sanctuary.

Pest species name	Potential impact	Abundance and biomass	Apparent impact
Undaria pinnatifida	4	5	4
Grateloupia turuturu	3	4	2
Sabella spallanzanii	4	2	2
Carcinus maenus	4	2	2
Asterias amurensis	5	1	1

How much of an impact are the IMPs having on Point Cooke Marine Sanctuary?

To assess the impact of the five more abundant IMPs at PCMS on the local ecosystem, we need to conduct further quantitative research. Until then we can use some 'guesstimates' as to what impacts they are having based solely on their abundance. Table 1 provides a snapshot of the sorts of impacts we might expect for the PCMS with regard to these five IMPs.

The situation relating to invasive marine pest species could perhaps be summarised as being of low concern due to the limited abundances of many marine pest species within the sanctuary. Even *U. pinnatifida* presents a problem for a maximum of only seven months of the year given its seasonal nature; the limited abundances of the other species appear to indicate that they may not be having an impact on the sanctuary at all. It is to be hoped that this situation continues into the future so that the biodiversity of this precious marine environment is not compromised further.

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A range extension of the introduced Black-keeled Slug *Milax gagates* (Draparnaud, 1801) (Eupulmonata: Milacidae) in northern inland New South Wales

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Abstract

This paper describes a record of the introduced Black-keeled Slug *Milax gagates* (Draparnaud, 1801) in Coonabarabran in northern inland New South Wales. This is a range extension of about 220 km north of the species' previously known distribution in the state. (*The Victorian Naturalist* **133** (5) 2016, 184–186)

Keywords: introduced slug, *Milax gagates*, range extension

Introduction

The Black-keeled Slug *Milax gagates* is a terrestrial slug in the family Milacidae with a native distribution across western Europe and the Mediterranean (Kerney 1999). It is found as an introduced pest species across the southern regions of Australia (Smith and Kershaw 1979; Smith 1992; Stanisic *et al.* 2010), with records in south-west Western Australia, south-east South Australia, Tasmania, Victoria, and southern New South Wales (Atlas of Living Australia 2015). There is also a 1975 record from Alice Springs, Northern Territory, and a 2011 record from Brisbane, Queensland (Atlas of Living Australia 2015). In its native range, the species is typically found in disturbed habitats including gardens, agricultural land and roadsides, as well as woods and coastal areas (Kerney and Cameron 1979; Kerney 1999). This may have preadapted it for the invasion of similar disturbed environments in Australia (Stanisic *et al.* 2010). In Australia it has also been found in forest plantations (Bonham *et al.* 2002) and native grasslands, particularly in peri-urban areas (Holland *et al.* 2007).

The distribution of this species is of interest as it is a major agricultural pest in the southern states, grazing on grain crops such as canola (Horne and Page 2004; Nash *et al.* 2007; Micic *et al.* 2008), and also impacting on community structure of native grassland by feeding on native grasses (Holland *et al.* 2007) and endangered flora including the daisy *Rutidosis leptorrhynchoides* (Daniell 1994).

This contribution documents a new record of *M. gagates* in Coonabarabran in northern inland NSW, which represents a northerly extension of the documented range of the species in NSW of about 220 km.

Observation

A single *Milax gagates* was recorded in the Coonabarabran urban area on a morning following rain in late August 2015. The species was identified by the diagnostic strongly keeled tail (Fig. 1). Coonabarabran is located on the western slopes of the Great Dividing Range, 350 km north-west of Sydney and 300 km from the east coast, in the Brigalow Belt South bioregion. The site (31° 16.96' S, 149° 16.15' E, Fig. 2) was a grassy laneway with a suburban lawn on one side and pasture grazed by horses on the other, and was about 30 m from a small vegetable garden.

Discussion

The Coonabarabran sighting of *Milax gagates* was made about 220 km north of Bathurst and Orange and 390 km north-west of Cooranbong, near Newcastle, which are the nearest records in NSW (Atlas of Living Australia 2015). It is the first of the species in the Brigalow Belt South bioregion. The species was not recorded in a survey of the Pilliga forest area (including Coonabarabran) by Murphy and Shea (2013). However, several other introduced land snail species were recorded as westerly range extensions, including *Bradybaena similaris*, *Vallonia excentrica*, *Hawaiia miniscula* and *Zonitoides arboreus*, and it was noted that further surveying of the area could identify additional species

Fig. 1. *Milax gagates*, Coonabarabran urban area. Photo MJ Murphy.

Fig. 2. Habitat of *Milax gagates* in Coonabarabran urban area. Photo JK Murphy.

(Murphy and Shea 2013). Similarly, Stanisic *et al.* (2010) noted that *M. gagates* had not yet been recorded in Queensland, but the species was subsequently found in Brisbane in 2011 (specimen number F178722) (Museum Victoria 2015). It is not known whether this indicates that the range of this species is expanding, or if it has simply escaped detection.

Milax gagates is a burrowing species and is able to shelter from desiccating conditions (Nash *et al.* 2007), which is indicated by the increase in the proportion of *M. gagates* in slug communities following drought (Hoffman *et al.* 2008), and may also explain the gradual expansion of the species' range to the north as seen in the recent records from Brisbane and Coonabarabran. A further advantage for this species is a higher level of resistance to conventional molluscicides, making it more difficult to control (Hoffmann *et al.* 2008; Micic *et al.* 2008). This may provide an advantage over other introduced slug species such as the surface-dwelling *Deroceras reticulatum* under dry conditions (Nash *et al.* 2007).

Milax gagates is already a major pest slug species in South Australia (Horne and Page 2004), and these advantages could result in an increasing impact on agricultural systems with increasing aridity due to climate change, leading to serious economic losses. There are also potential ecological impacts on native vegetation communities, as increasing populations of *M. gagates* could result in increased levels of herbivory on palatable species, which may have a negative impact on the survivorship of some threatened flora species, and could alter the structure and composition of affected vegetation communities (Holland *et al.* 2007). It is therefore a priority to document the distribution of introduced pest species such as *M. gagates*, to monitor and manage the impacts of these species on agricultural and native systems, especially with potentially increasing impacts due to the effects of climate change.

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Nudibranchs and related molluscs

by Robert Burn

Publisher: *Museum Victoria, Melbourne, 2015. 257 pages, paperback, colour photographs, 450 g. ISBN 9780980381382, RRP $34.95*

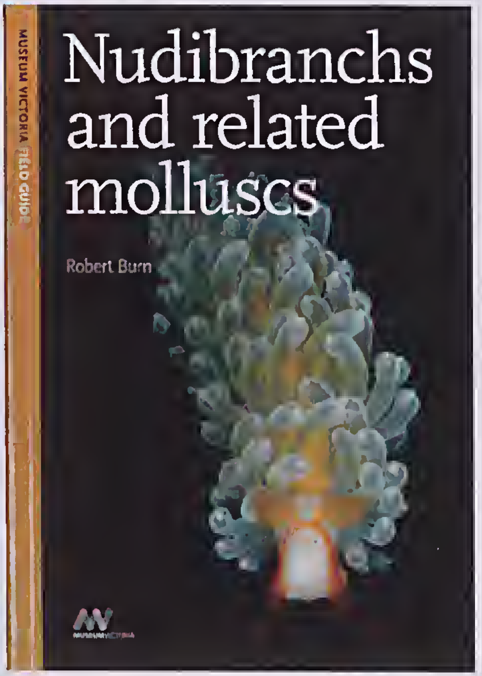
This book is the sixth in the Museum Victoria marine field guides series. The aim of the series is to enable amateur naturalists, beachcombers, divers and biologists to identify the commonly seen intertidal and shallow subtidal species along the Victorian coast. Previous books covered an introduction to marine life (2007), crabs (2007), barnacles (2009), sponges (2013) and shrimps and lobsters (2015). Nudibranchs include some of the most flamboyantly colourful members of the class Mollusca, and this book is a colourful and visually appealing addition to the series.

Robert Burn is both an amateur seashore naturalist and internationally respected authority on nudibranchs and related molluscs—an encouraging example showing that anyone with sufficient interest and enthusiasm can make a valuable contribution to scientific knowledge. Robert has authored or co-authored approximately 100 scientific papers, chapters in books such as *Fauna of Australia, Molluscs: The Southern Synthesis* (1988) and *Marine Invertebrates of Southern Australia* (1989), and has described more than 90 species, mostly from Victoria. This is his first book as sole author and is based on more than 60 years of amateur research along the coast of Victoria and nearby areas.

The first part of the book provides introductory information on the higher taxonomy, external and internal anatomy, reproduction, habitats, biotic relationships and behaviour of nudibranchs and related molluscs, followed by text descriptions and illustrations of 173 species of nudibranch and 76 other species including bubble shells, sap-sucking sea slugs, sea hares, umbrella shells and side-gilled slugs. The species descriptions are useful and not overly technical, and are supported by a glossary at the end of the book. The illustrations are a highlight of the book, with many eye-catching species including *Sagaminopteron ornatum*, *Doris chrysoderma*, *Okenia echinata*, *Tambja verconis*, *Thecacera pennigera*, *Burnaia helicochorda* and *Austraeolis ornata*.

I noticed only a few minor negatives. The book's title does not specify the geographic area of coverage (the Bass Strait area). This is consistent with other books in the series and is unlikely to concern a Victorian reader. The page layout of the species accounts was at first somewhat confusing, running across each two-page spread rather than down each page, but works well when understood. The ability of aeolids to retain nematocysts from their cnidarian prey for defence is mentioned on pages 12, 29, 30 and 204. A caution could have been included regarding handling aeolids, particularly *Glaucus* species likely to be found washed ashore, as the concentrated nematocysts can give people a sting more painful than man-of-war *Physalia* species (Rudman 1998). The illustration of *Burnaia helicochorda* (p. 209) shows the rare orange-bodied form rather than the more common white-bodied form—but it is a beautiful photograph.

Approximately a third of the species featured are identified by morpho-species codes rather than binomial names, indicating that they have not yet been formally described in the scientific literature. That a third of the more commonly seen species in Victoria are undescribed demonstrates how much remains to be discovered about nudibranchs and related species. This book will encourage and assist others to contribute to our knowledge of this interesting mollusc group as well as promoting community support for the protection of coastal environments. A commendable effort by the author.



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One Hundred and Two Years Ago

NATURAL HISTORY NOTES

Mr. C.J. Gabriel referred to his exhibit of mollusca from Portsea. During a recent holiday he was spending at Portsea the jetty happened to be under repair, a number of the piles being withdrawn and replaced by new ones. The old piles were found to be teeming with marine life, and many crustaceans, isopods, bryozoa, mollusca, and those numerous creatures which are so frequently relegated to the scientific rubbish-heap—the worms—were collected, and have been handed over to specialists for examination. The mollusca were particularly interesting and numerous. Three of our rarest chitons, *Acanthochites maughani*, Torr and Ashby, *A. speciosus*, Adams, and *A. kimberi*, Torr, may be mentioned. The Victorian cowries were well represented, but as the contractor and his men were equally keen in the search for them, they were difficult to obtain. All of the piles showed the destructive work of the ship-worms; one burrow, having a diameter of an inch, measured two feet in length.

From *The Victorian Naturalist* XXXI, p. 3, May 7, 1914